Total Factor Productivity (TFP) in the heavy manufacturing sector of Mexico (1993-2018).

Alejandro Ramirez[1]

[1]PhD. student in Economics
Durham University, United Kingdom.

April 7, 2021

Table of Contents

Table of Contents

Productivity: concepts.

Figure 1: Positive and negative factors to productivity as well as the outcomes of productivity.

a\ https://elpais.com/economia/2020/02/21/actualidad/1582300713_739014.html
b\ https://www.dw.com/es/ciudad-de-m%C3%A9xico-es-la-urbe-con-mayor-congesti%C3%B3n-de-autos-en-el-mundo/a-37660353
c\ https://www.milenio.com/deportes/mas-aficion/iaaf-instalara-monitores-calidad-aire-cdmx

(a) Positive: innovation.

(b) Negative: congestion.

(c) Outcomes: quality of life.

Table of Contents

Productivity: measurements.

Economic measurements of productivity, $Productivity = \frac{Output}{Inputs}$:

- $LP = \frac{Y}{L}$
- $TFP = \frac{Y}{f(K,L,M)} = A$

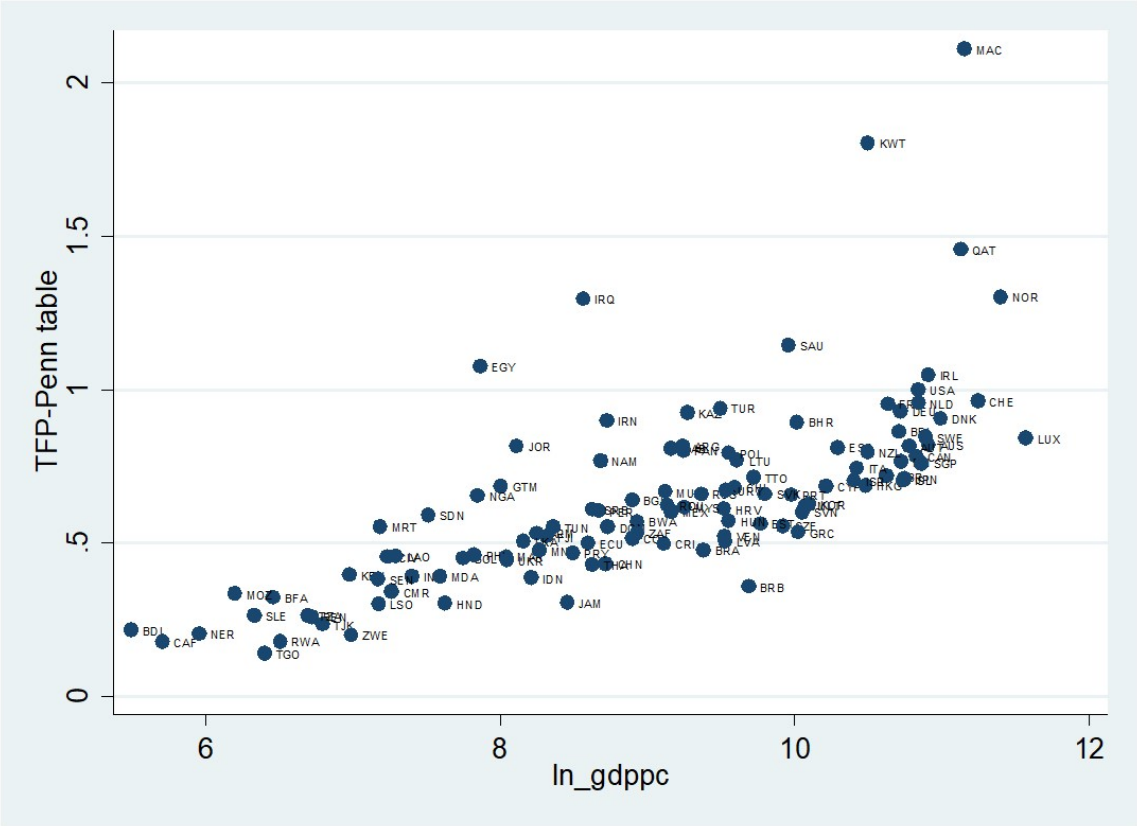
Total Factor Productivity (TFP) measures efficiency and technical progress, also known as multifactor productivity. The TFP is a key variable in the accounting of economic growth and methodologies to measure this variable are the following:

1. Parametrical methods: Econometric models (e.g. time-series, cross sections, panel data models).
2. Deterministic methods (Non-parametrical): (i) TFP indices (i.e. Laspeyres, Passche, Fisher and Tornqvist) and (ii) Data Envelopmet Analysis (DEA).
3. Theoretical economic models (e.g. Hopenhayn, 1992; Melitz, 2003; Hsieh and Klenow, 2009).

Table of Contents

TFP and GDP per capita across countries.

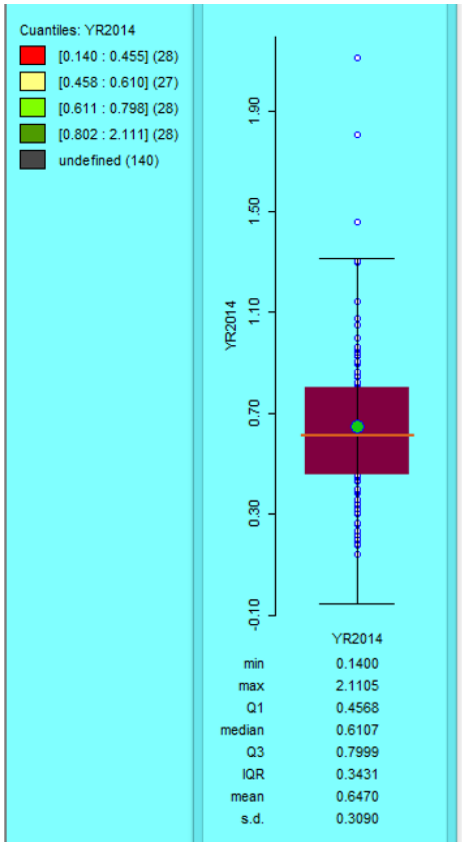
Figure 2: GDP per capital in logs (ln gdpc) and TFP at national level, 2014.

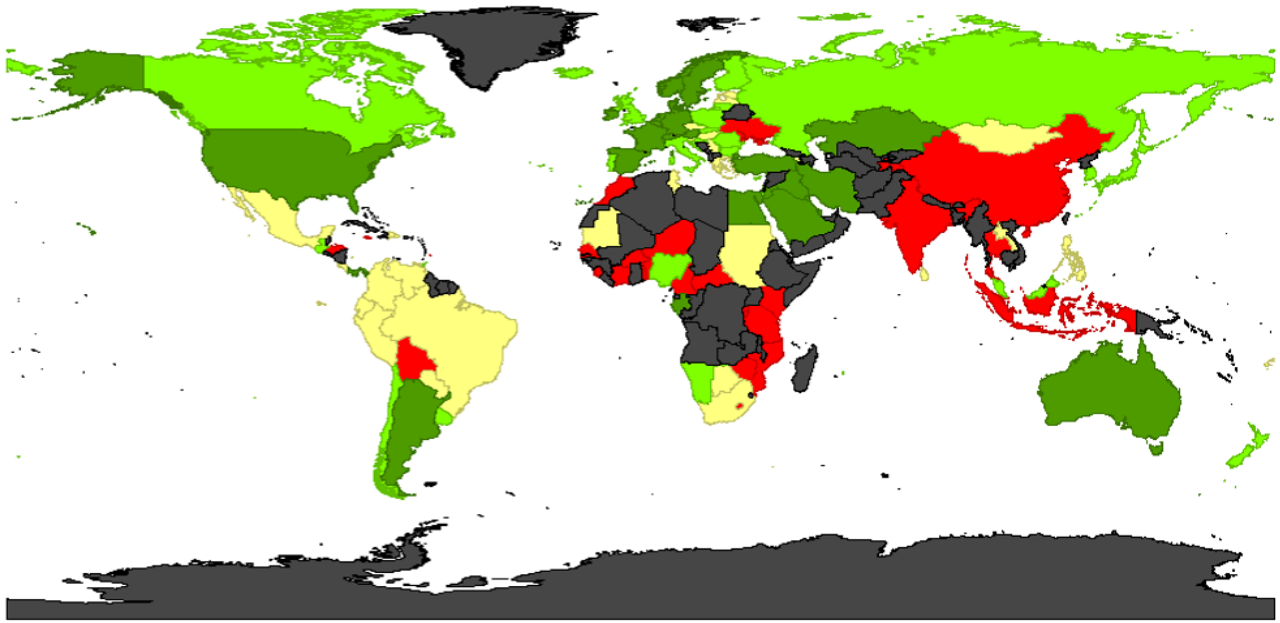


Source: Penn table: Feenstra, Robert C., Robert Inklaar and Marcel P. Timmer (2015)

An international comparison of TFP.

Figure 3: Geographical distribution of TFP at national level by quartiles, 2014

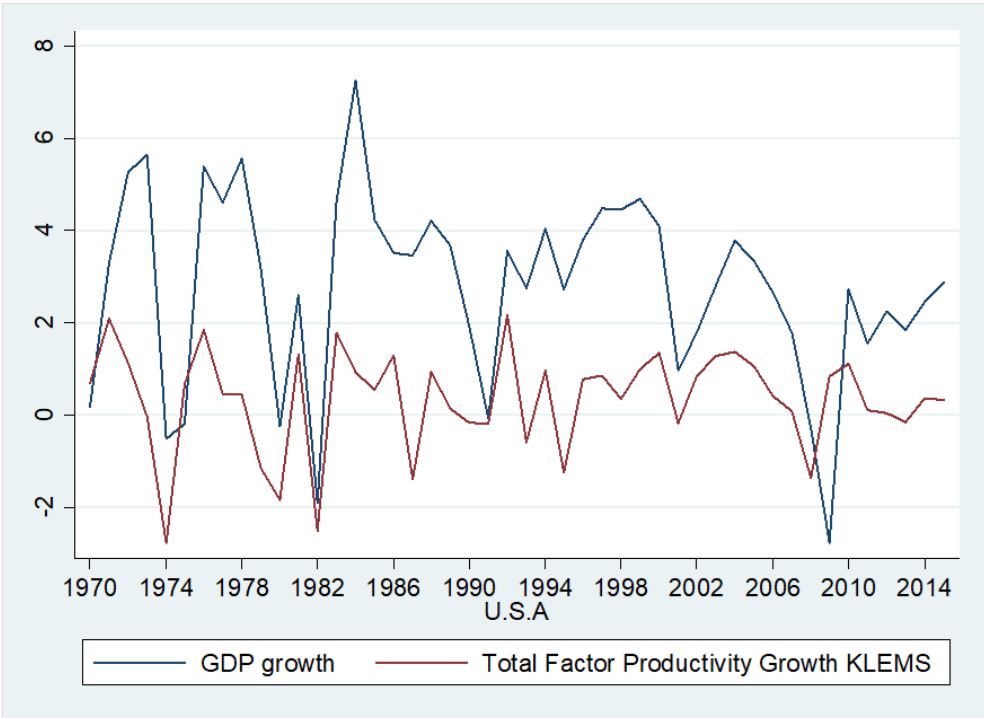




Source: Penn table: Feenstra, Robert C., Robert Inklaar and Marcel P. Timmer (2015)

TFP growth and GDP growth: U.S.A and U.K.

Figure 4: GDP growth and TFP growth in U.S.A. (1970-2015) and U.K. (1990-2015)



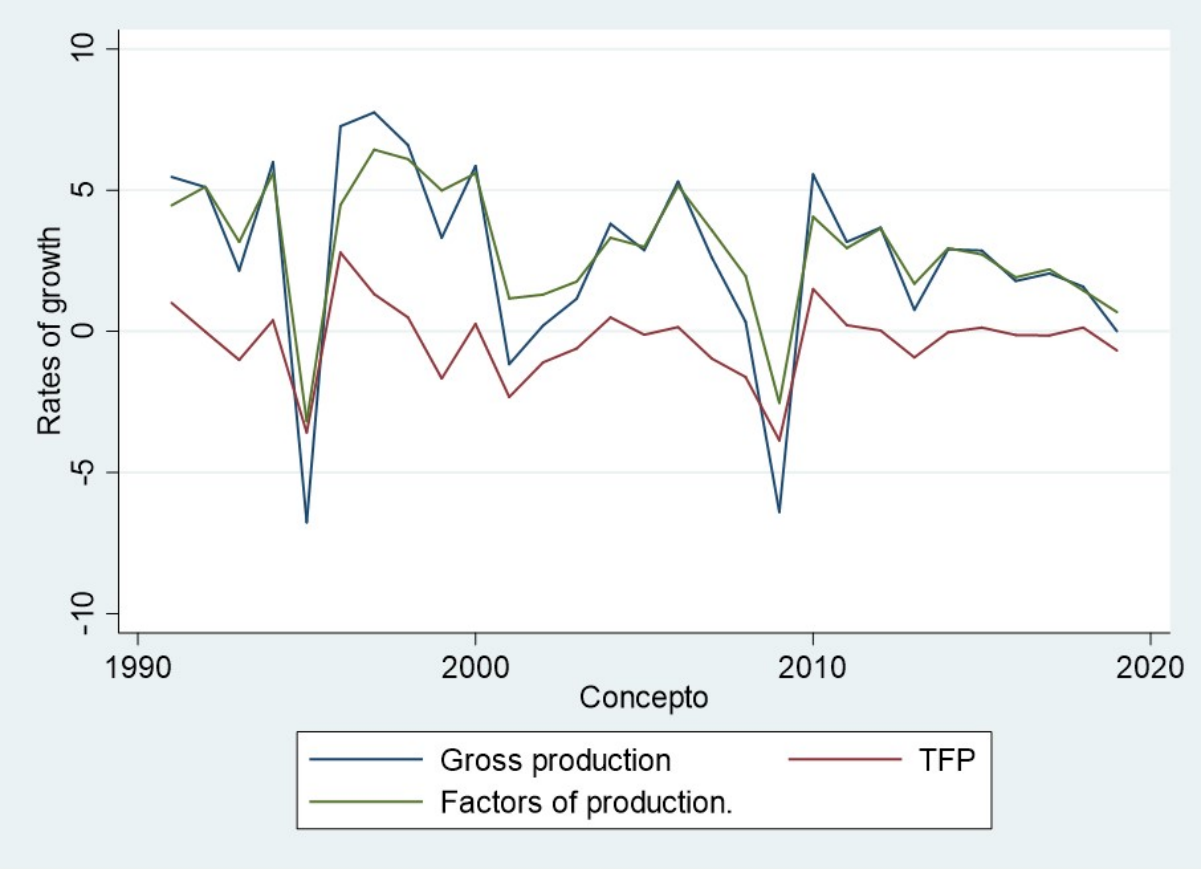
(a) U.S.A.

(b) U.K.

Source: Own elaboration with data of the KLEMS project and the World Bank.

TFP and production growth in Mexico.

Figure 5: TFP and gross production growth in Mexico, 1991-2019



Source: KLEMS model estimated by the National Institute of Statistics and Geography (INEGI) of Mexico

Table of Contents

Research contributions.

1. A parametrical comparison in the function of production across the estimation of Panel Data models applied to the heavy manufactruing sector in Mexico (NAICS 33).
2. The identification of TFP determinants as well as the model(s) with better parametrical fitness.
3. The statistical characteristics of the TFP distribution and TFP time-series across the models estimated.
4. The measurement of a TFP index with geographical disaggregation: national, state and local authority level —municipality—.

Table of Contents

The specification of the function of production

The output, or gross production, depends on the TFP, the inputs and the contextual variables of the local authority (municipality) i in time t. The following equation reflects this statement.

$$Y_{it} = A_{it} f(K_{it}, L_{it}, M_{it}, X_{it}) \tag{1}$$

In (1) Y, K, L, M are the output, capital, labour and intermediate inputs, respectively. Additionally, X is a vector of TFP determinants. The Cobb-Douglas function is an ad-hoc non-linear function of production to apply to $f()$ in (1), then:

$$Y_{it} = A_{it} f(K_{it}^{\beta_K}, L_{it}^{\beta_L}, M_{it}^{\beta_M}, X_{it}^{\beta_X}) \tag{2}$$

The specification of the function of production

The logarithmic transformation of (2) is:

$$y_{it} = \beta_0 + \beta_k k_{it} + \beta_l l_{it} + \beta_m m_{it} + x_{it}^{'}\beta_x + \epsilon_{it} \quad (3)$$

Parameters β's, including the constant term β_0, as well as the error term ϵ_{it} in the log-linear function of production in (3) can be estimated with econometric (parametric) methodologies. The TFP in logarithms is calculated as follows.

$$ln(A_{it}) = y_{it} - (\beta_k k_{it} + \beta_l l_{it} + \beta_m m_{it}) = \beta_0 + x_{it}^{'}\beta_x + \epsilon_{it} \quad (4)$$

To estimate the function of production in equation (4), it can be applied a pooled model (regression) using Ordinay Least Sqaures (OLS). However the application of this model leads to the endogeneity bias. The following models overcome this issue.

Table 1: Classification of Econometric Panel Data Models to estimate functions of prouction

Methodology	Category	Estimation	Model
Econometrics: Panel Data Models.	Idyiosincratic and time-invariant effects.	Within Estimator using Least Squares (LS).	Fixed Effects
	Stochastic Frontiers of Production (SF)	Maximum Likelihood Estimation (MLE)	Battese and Coelli (1988)
			Battese and Coelli (1992)
			Battese and Coelli (1995)
			Kutlu and Karakaplan (2018)
	Control Function Approach (CFA)	Two stages: First: LS. Second: GMM.	Olley and Pakes (1996)
			Levinsohn and Petrin (2003)
		General Method of Moments (GMM)	Wooldridge (2009)
	Dynamic Panel Data Models	GMM	System of GMM (SYS-GMM). Blundell and Bond (1998)

Table of Contents

Economic Census: A summary.

Table 2: Main variables of the Economic Census, 1993-2018

(a) General structure

Year	Number of establishments	Local authorities (municipalities)	Number states	Number of industries (4 digit NAICS)
1994	2,209,422	2,348	32	270
1998	2,804,984	2,421	32	243
2003	3,005,157	2,428	32	349
2008	3,724,019	2,446	32	344
2013	4,230,745	2,450	32	351
2018	4,800,157	2,461	32	268

(b) Output and factors of production.

Year	Gross production		Intermediate consumption		Total stock of fixed assets		Total workers	Exchange rate
	MXP (Trillion)	USD (Trillion)	MXP (Trillion)	USD (Trillion)	MXP (Trillion)	USD (Trillion)	Persons	Mexican Pesos (MXP) to U.S Dollars (USD)
1994	0.597	0.191	0.355	0.114	0.801	0.257	9,559,559	3.12
1998	3.719	0.406	2.076	0.227	2.531	0.276	13,681,210	9.16
2003	6.410	0.594	3.037	0.281	3.615	0.335	16,239,536	10.80
2008	11.236	1.008	5.912	0.530	5.927	0.532	20,116,834	11.15
2013	13.984	1.095	8.000	0.626	8.073	0.632	21,576,358	12.77
2018	22.191	1.153	12.219	0.635	11.556	0.601	27,117,313	19.24

(c) Working hours and wages

Year	Weekly average working hours	Monthly average wage		Hourly average wage	
	Hours	MXP	USD	MXP	USD
1994		1,425	457		
1998	44.4	3,177	347	71.6	7.8
2003	49.0	4,301	398	87.7	8.1
2008	45.4	4,679	420	102.9	9.2
2013	45.0	5,385	422	119.7	9.4
2018	46.1	6,397	333	138.8	7.2

Source: Own elaboration using the Economic Census of Mexico (INEGI)

Economic Census: Heavy manufacturing sector.

The heavy manufacturing sector produces metal machinery, electronics, electrical equipment, transports and furnitures (id 33 of the North American Industrial Classification, NAICS).

Table 3: Main variables of the Economic Census, All sectors and the heavy manufacturing sector (NAICS 33), 1993-2018

(a) General variables

Year	Number of establishments		%	Gross production (Trillion of MXP)		%
	Total	Manufacturing (NAICS)		Total	Manufacturing (NAICS)	
1993	2,175,326	73,286	3.37	0.409	0.143	
1998	2,731,445	91,574	3.35	2.930	0.451	15.38
2003	2,931,022	84,801	2.89	4.871	0.591	12.14
2008	3,640,348	110,505	3.04	8.338	1.099	13.19
2013	4,145,552	120,213	2.90	10.574	1.464	13.84
2018	4,708,860	125,438	2.66	17.376	3.266	18.79

(b) Factors of production.

Year	Intermediate inputs (Trillion of MXP)		%	Fixed assets (Trillion of MXP)		%	Employment (Persons)		%
	Total	Manufacturing (NAICS)		Total	Manufacturing (NAICS)		Total	Manufacturing (NAICS)	
1993	0.035	0.097		0.493	0.065		9,228,595	957,615	
1998	1.580	0.298	18.86	1.606	0.189	11.74	12,634,237	1,374,842	10.88
2003	2.220	0.356	16.04	2.277	0.266	11.69	14,819,767	1,365,191	9.21
2008	4.190	0.682	16.28	3.804	0.364	9.57	18,626,752	1,636,907	8.79
2013	5.520	1.050	19.02	6.626	0.442	6.68	20,025,433	1,843,212	9.20
2018	8.910	2.120	23.79	9.437	0.878	9.30	25,354,451	2,634,055	10.39

Source: Own elaboration using the Economic Census of Mexico (INEGI)

Database structure: Unbalanced Panel Data

Table 4: The panel dataset in the heavy manufacturing sector (NAICS 33), 1993-2018

	Local_authority	NAICS_4dig~s	Year	ln_y	ln_m	ln_l	ln_k
1	Aguascalientes, Ags.	3312	2003	-3.346284	-3.91251	4.276666	-5.285876
2	Aguascalientes, Ags.	3312	2018	-.7314516	-1.040027	5.793014	-2.215882
3	Aguascalientes, Ags.	3314	2008	-3.32331	-3.636615	4.094345	-4.445341
4	Aguascalientes, Ags.	3315	1993	-1.668768	-2.459861	5.659482	-1.864786
5	Aguascalientes, Ags.	3315	1998	-1.7598	-1.985638	5.517453	-4.245028
6	Aguascalientes, Ags.	3315	2003	-2.659972	-2.855462	4.70953	-4.318557
7	Aguascalientes, Ags.	3315	2018	.1848076	-.1381777	5.869297	-3.129086
8	Aguascalientes, Ags.	3321	1998	-4.260289	-4.913782	4.343805	-5.198758
9	Aguascalientes, Ags.	3322	1998	-2.217334	-4.494533	4.941642	-2.365414
10	Aguascalientes, Ags.	3322	2003	-1.681594	-2.523137	5.347107	-2.041095
11	Aguascalientes, Ags.	3322	2008	-1.397812	-1.883024	5.488938	-2.810673
12	Aguascalientes, Ags.	3322	2013	-1.579476	-1.994615	5.560682	-2.726744
13	Aguascalientes, Ags.	3322	2018	-1.223083	-1.508774	5.31812	-4.16069
14	Aguascalientes, Ags.	3323	1998	-1.413225	-1.801222	6.886532	-2.403678
15	Aguascalientes, Ags.	3323	2003	-.5892394	-1.09082	7.17549	-1.810389
16	Aguascalientes, Ags.	3323	2008	-1.351356	-1.862591	7.290293	-2.247481
17	Aguascalientes, Ags.	3323	2013	-1.095543	-1.680048	7.372118	-1.789905
18	Aguascalientes, Ags.	3323	2018	-.78018	-1.264676	7.542744	-1.854077
19	Aguascalientes, Ags.	3324	1993	-.7700554	-1.205817	7.242798	-1.724124
20	Aguascalientes, Ags.	3324	1998	-2.9082	-3.340893	4.025352	-4.532707
21	Aguascalientes, Ags.	3324	2003	-2.809589	-3.386506	4.382027	-4.334447
22	Aguascalientes, Ags.	3324	2008	-2.647792	-2.879291	4.382027	-5.266406
23	Aguascalientes, Ags.	3324	2013	-2.928111	-3.170538	4.330733	-4.501351
24	Aguascalientes, Ags.	3324	2018	-3.067023	-3.479327	4.143135	-4.29633
25	Aguascalientes, Ags.	3326	1998	-3.533266	-4.667511	3.583519	-5.588855

Source: Own elaboration using the Economic Census of Mexico (INEGI)

Table of Contents

Contribution (1). Parametrical comparison.

Table 5: Estimation with different econometric methods of the log-Cobb-Douglas function of production in the heavy manufacturing industry in Mexico (NAICS 33), 1993-2018.Factors of production.

	FE	BC88	BC92	BC95	KK17	OP	LP	LP-ACF	Wooldridge
ln intermediate inputs	0.816***	0.816***	0.816***	0.815***	0.799***	0.802***	0.821***		0.847***
	(242.172)	(211.035)	(208.822)	(197.791)	(279.645)	(241.540)	(216.780)		(158.030)
ln capital	0.028***	0.040***	0.040***	0.042***	0.050***	0.048***	0.031***	0.329***	0.026***
	(11.036)	(14.079)	(14.071)	(14.552)	(19.381)	(5.851)	(6.945)	(102.756)	(7.010)
ln employment	0.177***	0.193***	0.191***	0.190***	0.205***	0.200***	0.189***	0.825***	0.171***
	(36.969)	(31.546)	(30.623)	(30.381)	(60.483)	(40.346)	(38.801)	(154.604)	(32.092)
Observations	24,045	24,045	24,045	24,045	17,896	17,896	24,045	23,881	14,643

(t-statistics) (z-statistics) in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Source: Own estimation using the Economic Census of Mexico (INEGI).

Contribution (2). Identification of TFP determinants.

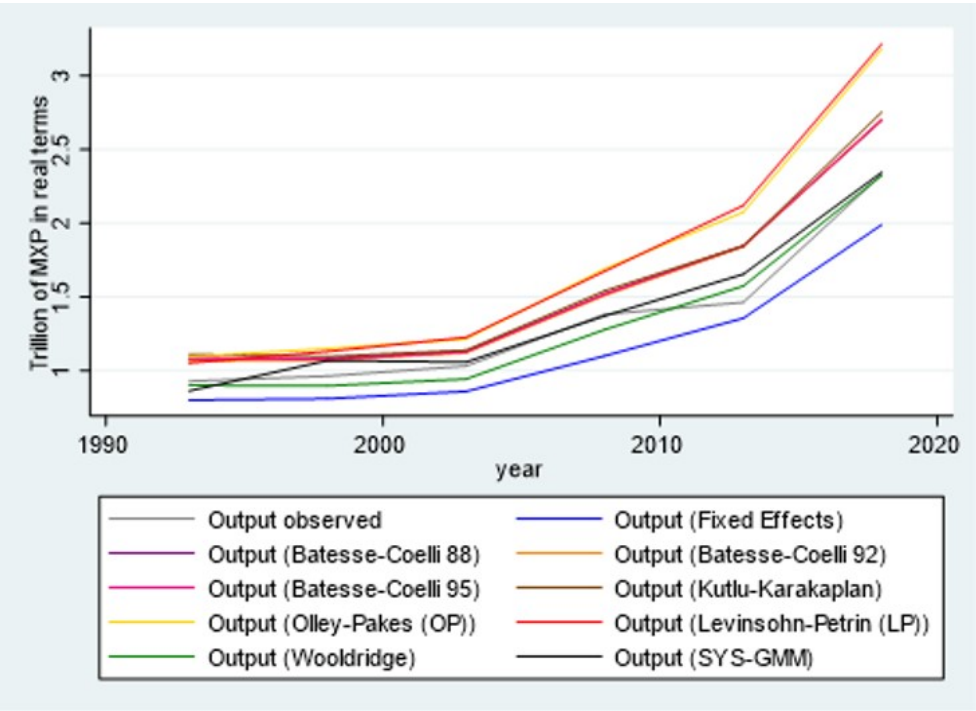
Table 6: Significance and sign of the variables included in the log Cob-Douglas function of production, 1993-2018.

Variables	Column (1) Statistically significant**		Column (2)	Column (3)
	Positive	Negative	No significant	Not included
ln intermediate inputs	9	0	0	1
ln capital	10	0	0	0
ln labour	10	0	0	0
ln Diversification index.	3	6	1	0
ln Agglomeration index.	9	1	0	0
ln Herfindahl index.	9	0	1	0
Time-trend	6	0	4	0
Urban areas	6	1	3	0
ln managerial efficiency	1	4	5	0
Constant term	0	5	1	4

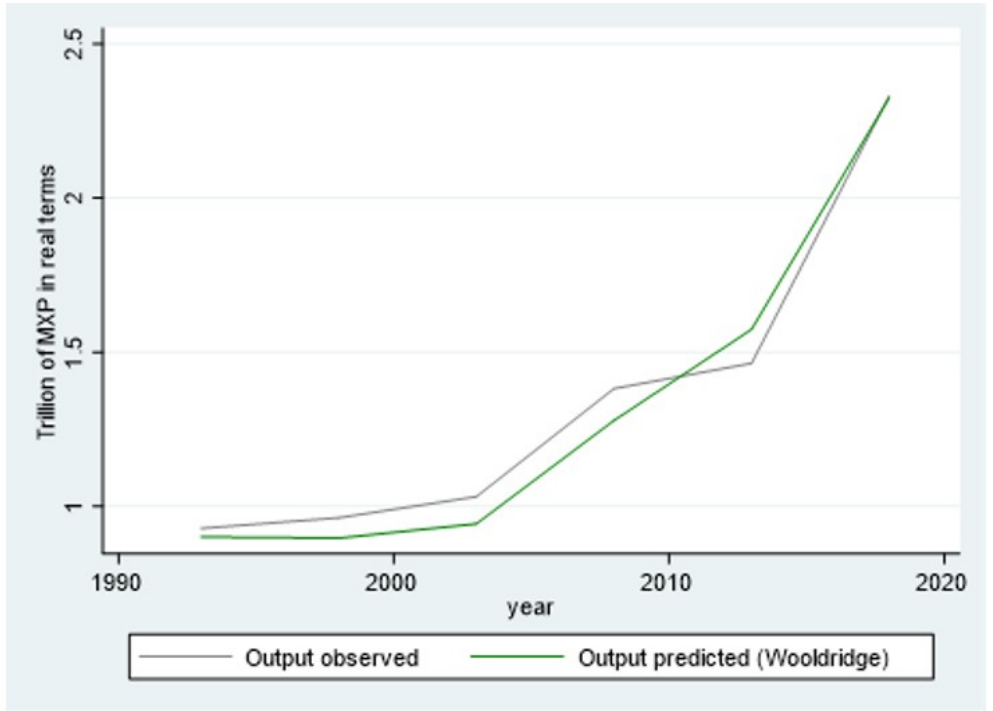
Source: Own estimation using the Economic Census of Mexico (INEGI).

Contribution (3). Identification of parametrical fitness.

Figure 6: Output observed and output estimated with different parametric methods in the heavy manufacturing industry in Mexico, 1993-2018.



(a) Observed vs Different methods.

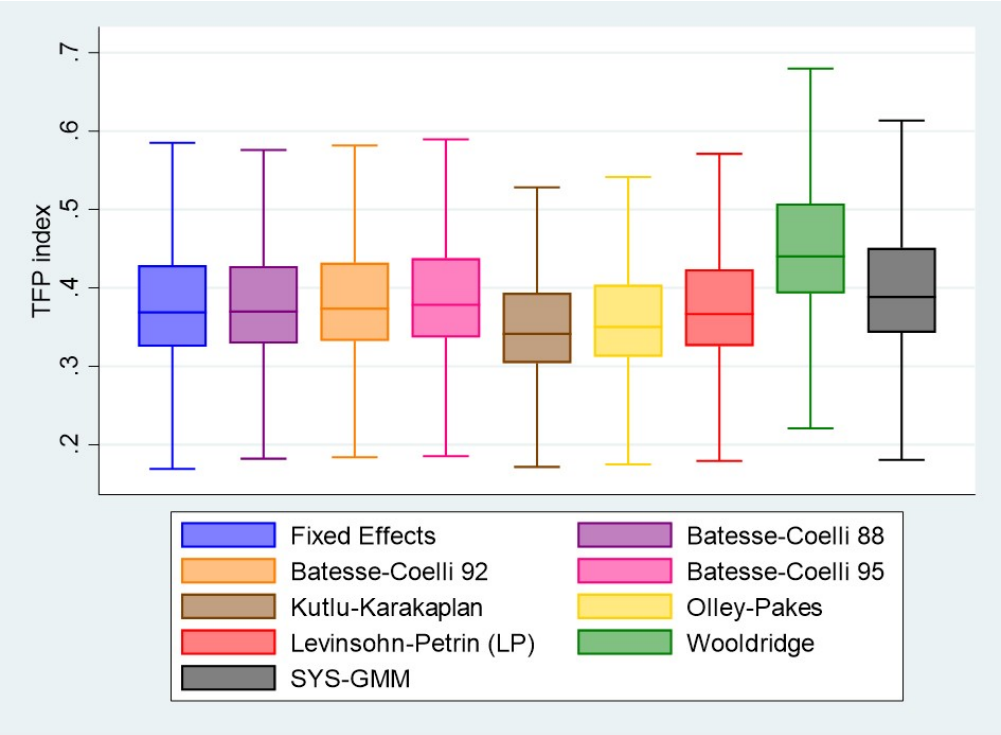


(b) Observed vs Method with the best fitness.

Source: Own estimation using the Economic Census of Mexico (INEGI).

Contribution (3). TFP distributions: different methods.

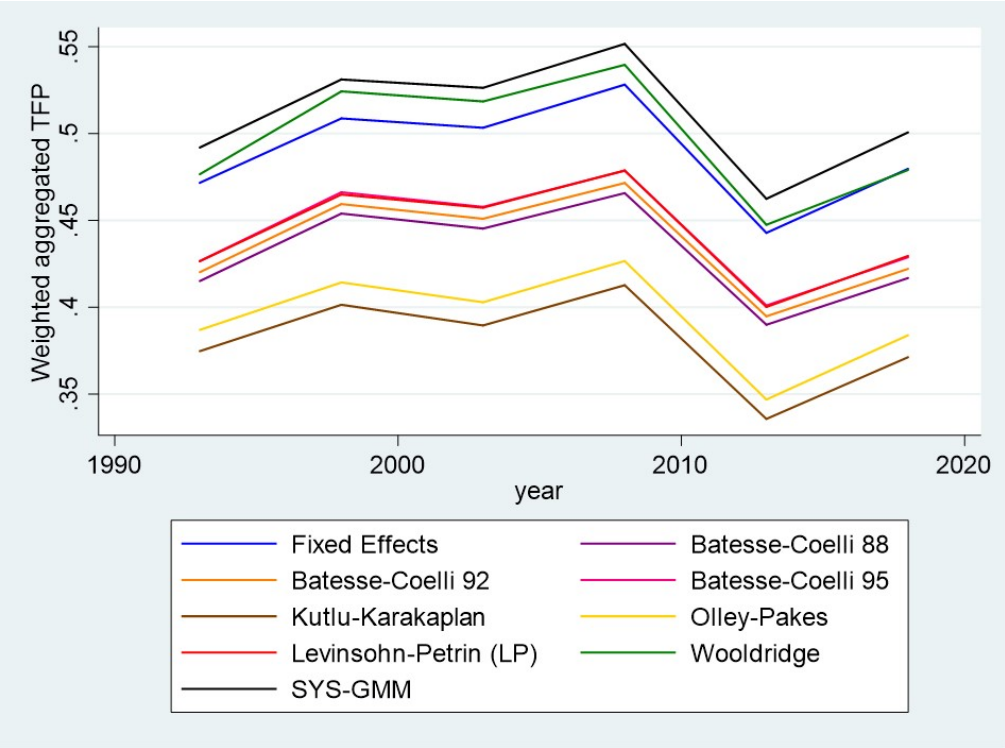
Figure 7: TFP distributions estimated with different parametric methods in the heavy manufacturing industry in Mexico, 1993-2018.



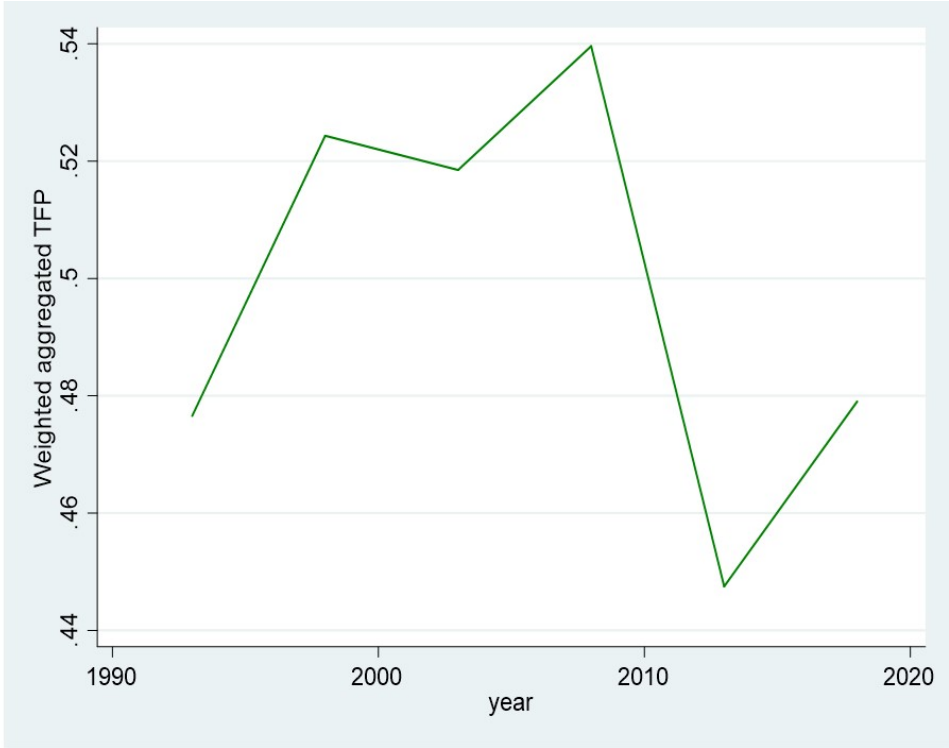
Source: Own estimation using the Economic Census of Mexico (INEGI).

Contribution (4). TFP at national level.

Figure 8: TFP index weighted and aggregated at national level in the heavy manufacturing industry in Mexico, 1993-2018.



(a) Observed vs Different methods.

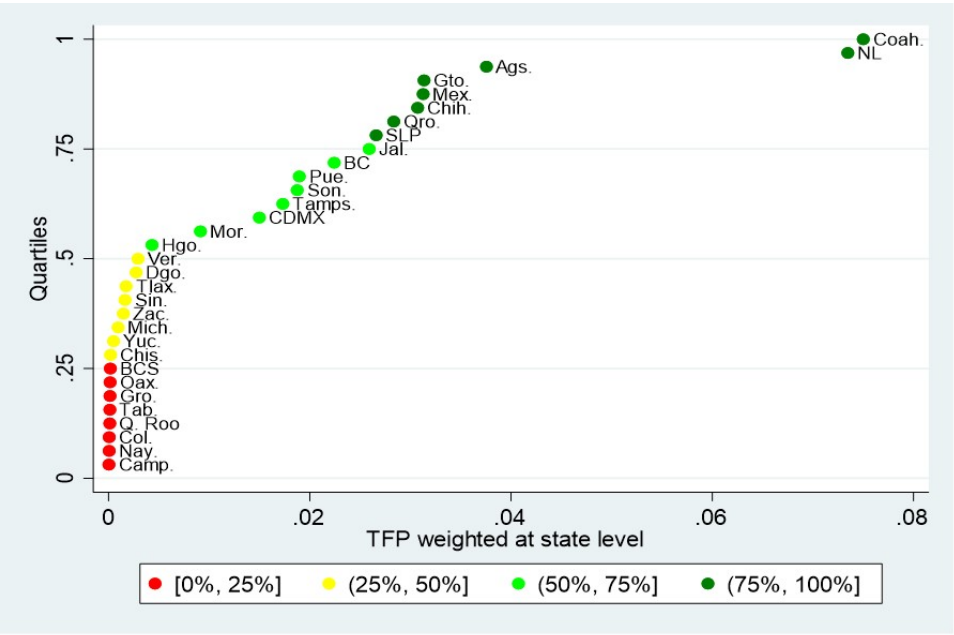


(b) Observed vs Method with best fitness.

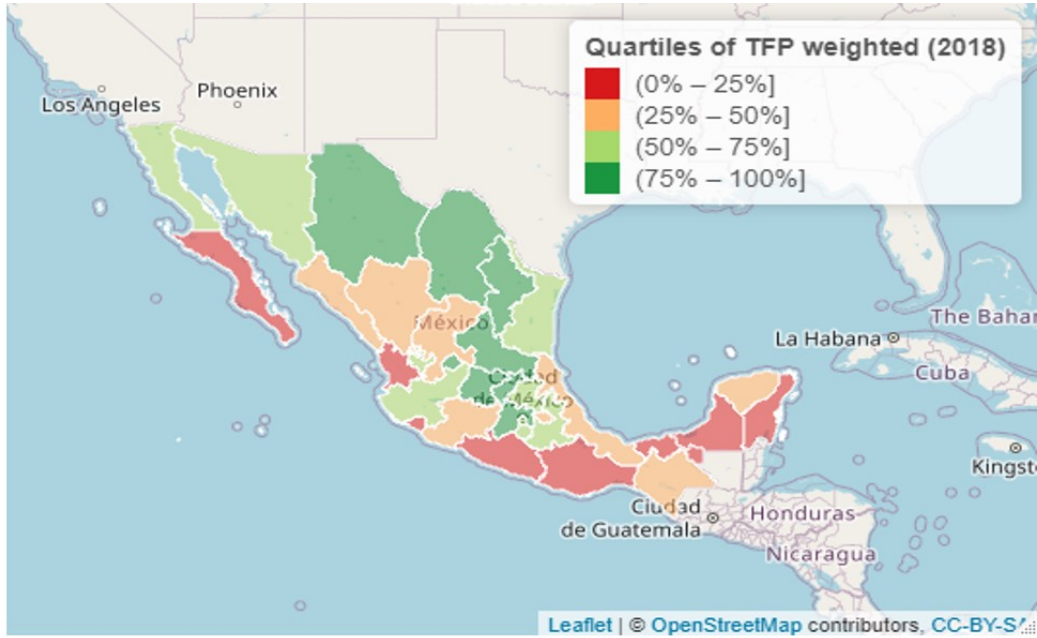
Source: Own estimation using the Economic Census of Mexico (INEGI).

Contribution (4). TFP index at state level.

Figure 9: TFP index weighted and aggregated at state level in the heavy manufacturing industry in Mexico estimated with Batesse and Coelli (92), 2018.



(a) TFP index at state level by quartiles.

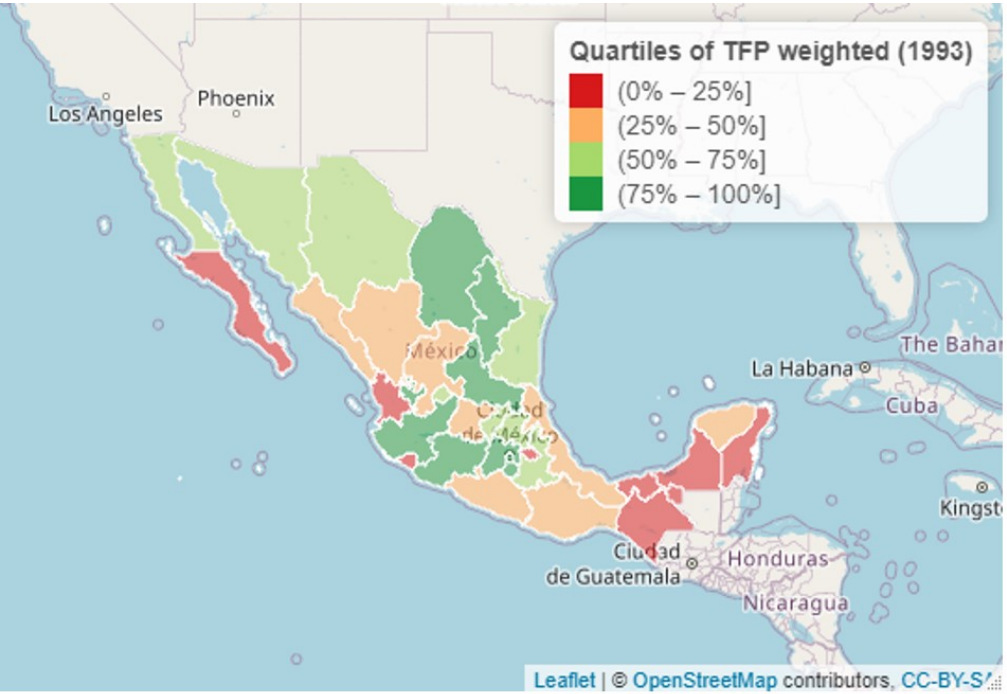


(b) TFP: geographical distribution.

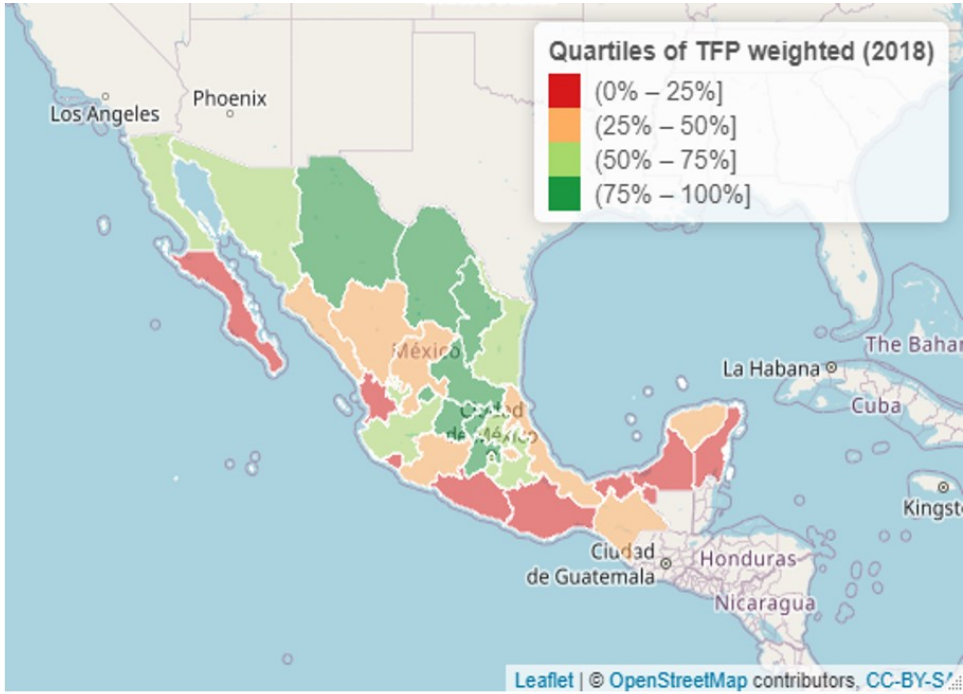
Source: Own estimation using the Economic Census of Mexico (INEGI).

Contribution (4). TFP index at state level.

Figure 10: TFP index weighted and aggregated at state level in the heavy manufacturing industry in Mexico estimated with Batesse and Coelli (92), 1993 vs 2018.



(a) TFP: geographical distribution, 1993.



(b) TFP: geographical distribution, 2018.

Source: Own estimation using the Economic Census of Mexico (INEGI).

Contribution (4). TFP index at local authority level (municipality).

Figure 11: TFP index weighted and aggregated at local authority level in the heavy manufacturing industry in Mexico estimated with Batesse and Coelli (92), 2018.

▸ Link

Source: Own estimation using the Economic Census of Mexico (INEGI).

Table of Contents

Conclusions.

- Elasticities of the intermediate inputs have higher values in comparison to capital and labour. Despite the heavy manufactruing sector has higher technology than other sectors, the elasticity of the labour factor is four times higher than the capital factor indicating that the overall sector is intensive in labour. The TFP determinants have following effect:
  - Negative: diversification index.
  - Positive: agglomeration index, Herfindahl-Hrischman index, urban areas, time-trend.
  - No significant: managerial efficency.
- There is a trade-off by using SF models is a good fitness in exchange to avoid large datasets.
- TFP with Economic Census. Limitation: time accuracy due to the 5 years gap of the information. Major advantage: a productivity spatial analysis due to the level of disaggregation.

Conclusions.

- The median of the TFP distribution is between 39-44 percent in a range of 0-100 percent during 1993-2018.
- There is not a clear time-trend in the estimated TFP at national level.
- The TFP spatial distribution shows that the heavy manufacturing increases its productivity due to the proximity with U.S. —northern Mexican states— and the high urban concentration —surrounding states of Mexico City and Jalisco—. This fact reflects the regional imbalance of productivity within Mexico.
- The estimation of a TFP index at local authority level —municipality— is a guide for policy makers to design an industrial strategy oriented to enhance the productivity in Mexico.

References

- Battese, G. E., & Coelli, T. J. (1988). Prediction of firm level technical inefficiencies with a generalized frontier production function. Journal of econometrics, 38, 387-399.
- Battese, G. E., & Coelli, T. J. (1992). Frontier production functions, technical efficiency and panel data: with application to paddy farmers in India. Journal of productivity analysis, 3(1-2), 153-169.
- Battese, G. E., & Coelli, T. J. (1995). A model for technical inefficiency effects in a stochastic frontier production function for panel data. Empirical economics, 20(2), 325-332.
- Blundell, R.W. and S.R. Bond (1998). Initial Conditions and Moment Restrictions in Dynamic Panel Data Models, Journal of Econometrics, 87, 115-143.
- Feenstra, R. C., Inklaar, R., & Timmer, M. P. (2015). The next generation of the Penn World Table. American economic review, 105(10), 3150-82.
- Hopenhayn, H. A. (1992). Entry, exit, and firm dynamics in long run equilibrium. Econometrica: Journal of the Econometric Society, 1127-1150.
- Hsieh, C. T., & Klenow, P. J. (2009). Misallocation and manufacturing TFP in China and India. The Quarterly journal of economics, 124(4), 1403-1448.
- Levinsohn, J., & Petrin, A. (2003). Estimating production functions using inputs to control for unobservables. The review of economic studies, 70(2), 317-341.
- Melitz, M. J. (2003). The impact of trade on intra-industry reallocations and aggregate industry productivity. econometrica, 71(6), 1695-1725.
- Olley, G. S., & Pakes, A. (1996). The Dynamics of Productivity in the Telecommunications Equipment Industry. Econometrica, 64(6), 1263-1297.
- Wooldridge, J. M. (2009). On estimating firm-level production functions using proxy variables to control for unobservables. Economics letters, 104(3), 112-114.

Appendix I

Table 7: Description of variables used to estimate TFP.

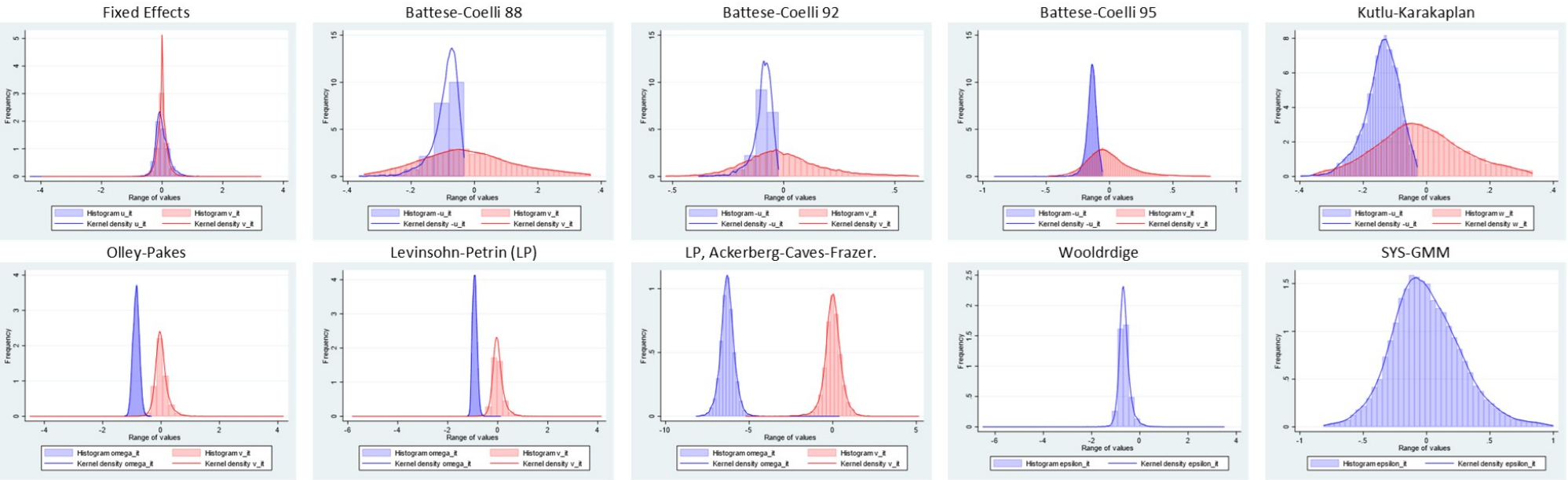
Variable	Description
ln gross output	*ln* gross production (billion MXP 2013 prices)
ln value added	*ln* (sales - intermediate inputs), (billion MXP 2013 prices)
ln intermediate inputs	*ln* intermediate inputs (billion MXP 2013 prices)
ln capital	*ln* real net tangible fixed assets (billion MXP 2013 prices)
ln labour	*ln employed persons.*
ln Diversification index.	*ln proportion of 4-digit NAICS industries by year (maximum 275) within the local authority level areas (2,461)– Jacobian spillovers*
ln Agglomeration index.	*ln % of industry output (2-digit NAICS) in each State– MAR-spillovers*
ln Herfindahl-Hiirschamn index.	*ln Herfindahl-Hirscham index of industrial concentration. This index is measured as the output contribution of the local authority (4-digits NAICS) to the total sectorial output (2-digit NAICS) at sectorial level by year.*
Time-trend	*Linear trend. ID of the year 2000=1, 2002=2, 2004=3, 2006=4*
Urban areas	*Dummy variable = 1 if population of the local authority is >=100,000 persons**
ln interest coverage ratio	*ln(total revenues/interest of credit paid)*
ln management efficiency	*ln(expenses in marketing, accessories, rent and professional services/total expenses)*

*The data of population was collected from the Census of Population and Housing in Mexico. There were calculated average intermediate points for the 5-year gap of this source.

Source: Own elaboration.

Appendix II

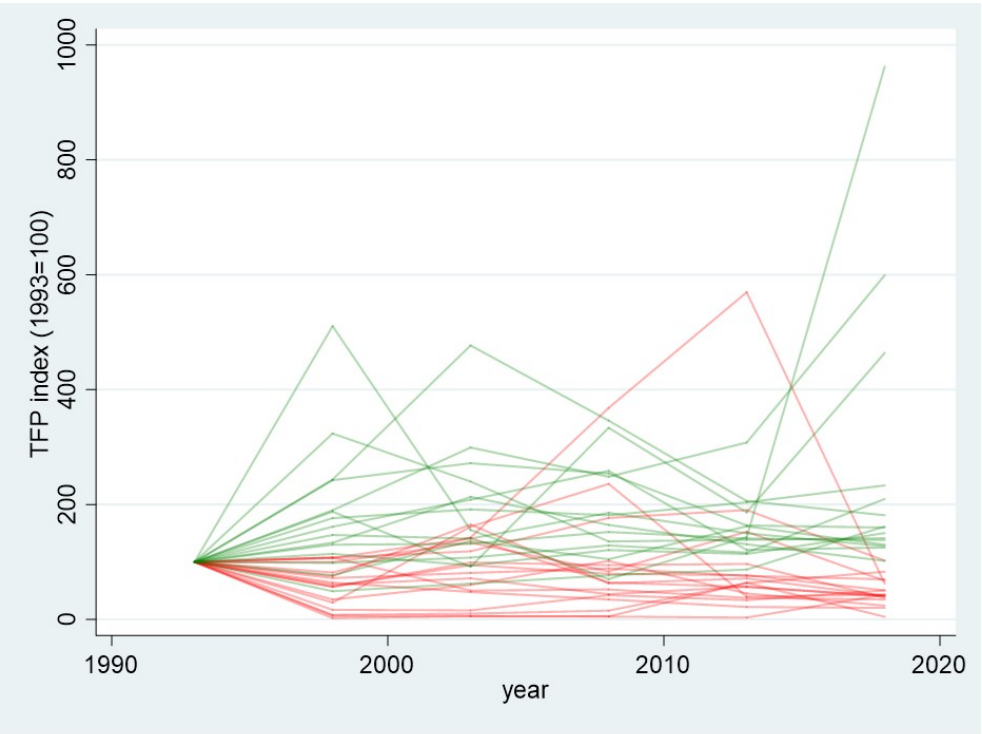
Figure 12: Error term distributions of the function of production: econometric models.



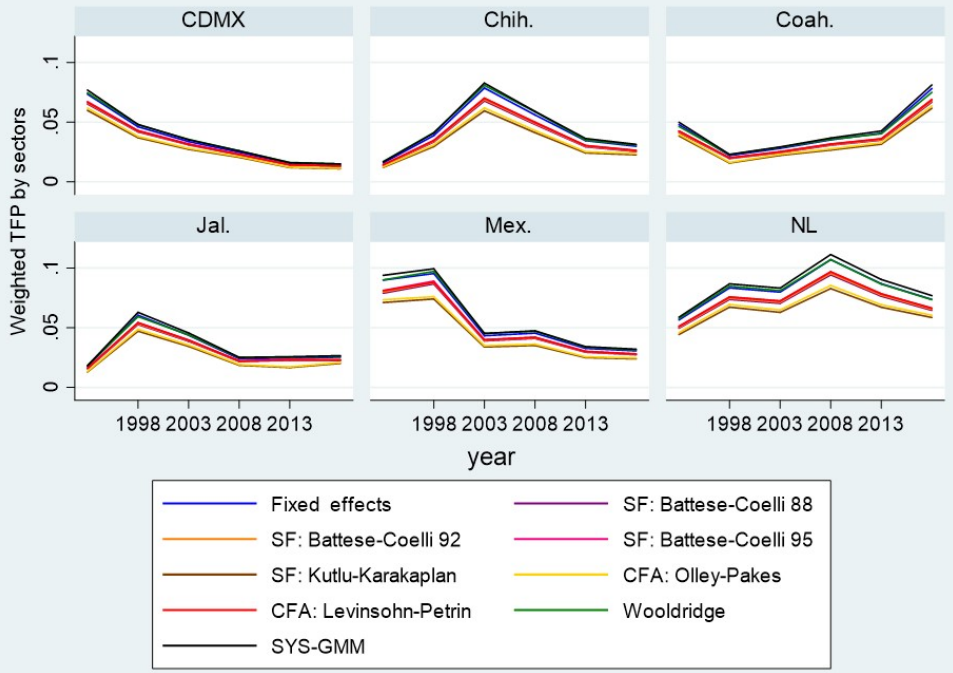
Source: Own estimation.

Appendix III

Figure 13: Aggregated weighted TFP index at state level, 1993-2018.



(a) Index (1993=100).



(a) State with highest TFP in 1993.

Source: Own estimation using the Economic Census of Mexico (INEGI).